

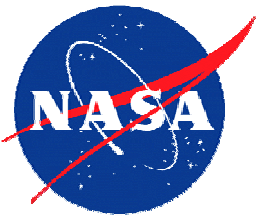
# Highly Engineered Materials Properties

## A Material Characterization Study

H. Phillip Stahl

James M Carter

NASA/Marshall Space Flight Center



# Highly Engineered Materials Properties

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## Background

NASA “Innovative Technology Transfer Partnership”

- Industry/NASA share program cost

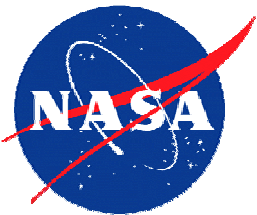
- Industry supplies samples for testing

- NASA does the testing

Industrial Liasion: Tom Culver/RTI

- Coordinated with potential Industry partners

- Assisted in test definition / sample requirements



# Test Plan

## OBJECTIVE

Provide definitive data on materials using consistent process.  
Data is independent of Vendors & Traceable to known Standards.  
Characterize Vendor's Process and Uniformity

## APPROACH

Progressive Down-Select Program

Materials must pass Phase 1 tests to reach Phase 2 testing.

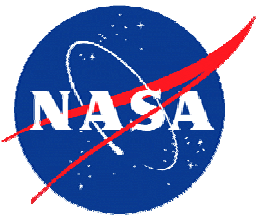
Test in batches to study uniformity and lot-to-lot variability.

Phase 1 Testing examines samples from 2 independent lots.

Phase 2 Testing examines samples from 3 additional processing lots.

Temperature Range from Ambient to 30K.

All decisions regarding material-vendor pass/fail will be handled by  
Lead Technologist and Advisory Committee.



# Highly Engineered Materials Properties

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Eight companies have signed agreements with NASA:

Bennett Optical

GE

M-Cubed

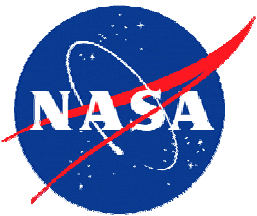
POCO

Schafer

SSG

TREX

Willsbank-CoorsTek



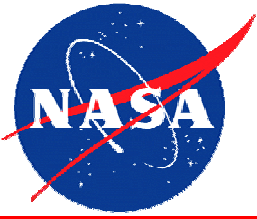
# Proposed Test Flow

## **Phase 1 – test 2 lots**

Incoming Microscopic Evaluation; Polish if appropriate; Microscopic Evaluation  
Cryogenic Strain tests  
Metallography Analysis/Chemical analysis  
Microstructure analysis/X-Ray Diffraction  
Density/Porosity Measurements

## **Phase 2 – test 5 lots**

CTE RT – 77(30)K  
Thermal Conductivity RT – 77(30)  
Tensile Strength and Elastic Modulus RT – 77(30)K  
4-point Bending Tests RT – 77(30)K  
Fracture toughness RT – 77(30)K  
Analysis: Metallography, Chemical, Microstructure, X-Ray Diffraction  
Density/Porosity Measurements  
Any tests which can be done at 4K for consideration



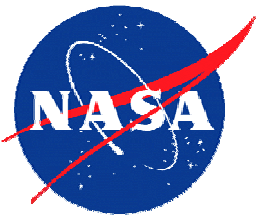
# Highly Engineered Materials Properties

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## Status

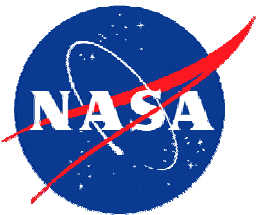
Samples from six vendors in house

Will start phase 1 test activities early FY07



# Backup

Test Details & Specifications



# Phase 1: Microscopic Evaluation

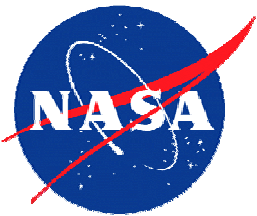
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**Objective:** Investigate surface morphology prior to and after polishing. Most specimens will be polished using a diamond abrasive. This test can reveal surface degradation due to processing.

**Test Method:** Micro-photographic recordings of surface pre/post polishing.

**Sample Description:** In total 4+ samples per vendor will be used for this test, 2+ from each of two processing lots, including bulk and capped samples as appropriate.





# Phase 1: Cryostrain

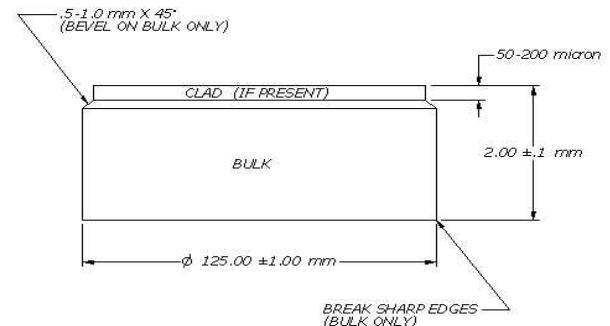
**Objective:** This test measures changes in sample figure from room temperature to 30K in one plane only. The data output will be figure maps/root mean square values as a function of temperature.

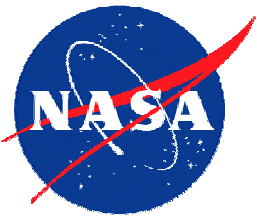
**Test Method:** An interferometric test will be performed under vacuum from room temperature to 30K. One test run of about 7-9 days will test a vendor's samples. These test will be done at room temperature, 200K, 100K, 70K, 50K, 30K, and room temperature: one cycle only Data output will be figure change versus temperature.

**Sample Description:** Samples will be figured/polished  $\frac{1}{4} \lambda$  PV and 100 Å rms or best effort. Vendor will supply 1 uncapped – 1 capped sample from 2 lots/batches. If uncapped sample is not polishable, then supply 2 capped samples from 2 batches.

Qty	Description	Diameter	Width	Thickness
2s/2l/p1	Disk Sample, RT - 30K	125 mm		see below

CRYO-STRAIN SAMPLE CONFIGURATION





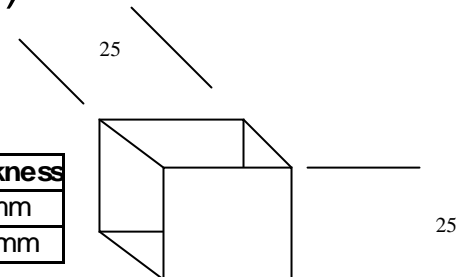
# Phase 1 & 2: Chemical Analysis

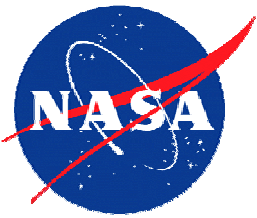
**Objective:** This test will show intra-sample and batch-to-batch variations in chemical composition of material-vendor processes. This information can also be used to critique the material-vendor overall quality control. Chemical analysis (microanalysis) using the scanning electron microscope (SEM) provides elemental composition of materials.

**Test Method:** The test will be done to ASTM Standard E1508.

**Sample Description:** These measurements will only be done at room temperature. Phase 1 samples will be the cryo disks; Phase 2 – two samples each from 3 additional lots will be a “cube”. (will be used for many Phase 2 tests)

Qty	Description	Diameter	Length	Width	Thickness
2s/2l/p1	Disk Sample RT	125mm d			2 mm
2s/3l/p2	"Cube" Sample		25 mm	25 mm	25 mm





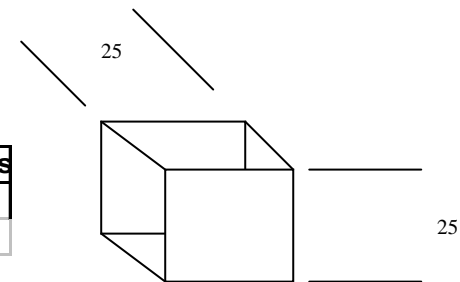
# Phase 1 & 2: Metallography Analysis

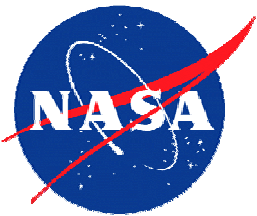
**Objective:** Investigate surface morphology changes due to polishing.  
All specimens will be polished using a diamond abrasive.

**Test Method:** Micro photographic recordings of surface pre/post polishing. This test can reveal surface degradation due to processing.

**Sample Description:** For Phase 2, the vendor will supply 2 samples, 1 uncapped – 1 capped or 2 capped, from 3 lots. If capping is required for polishing, then all samples will be capped. Phase 1 will use cryo disk samples.

Qty	Description	Diameter	Length	Width	Thickness
1s/2l/p1	Disk Sample RT	125mm d			2 mm
2s/3l/p2	"Cube" Sample RT		25 mm	25 mm	25 mm





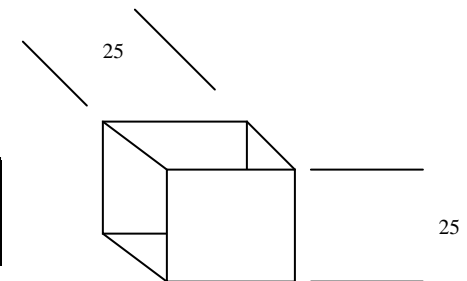
## Phase 1 & 2: Density/Porosity

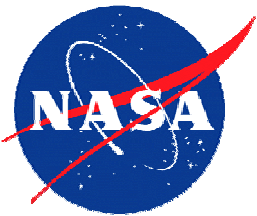
**Objective:** To measure the density and porosity which may be useful as indicator of process repeatability.

**Test Method:** The density will be determined by measuring the mass and volume of the specimens. The porosity will be determined by measuring the mass of the specimens before and after placing it in boiling water and allowing it to become fully saturated. The apparent porosity is calculated according to  $P=(W-D)/V$  where  $W$ =wet mass,  $D$ =dry mass and  $V$ =volume. This measurement is based on ASTM C 20. Measurements will be done at room temperature, only.

**Sample Description:** For Phase 2 the vendor will supply 2 samples, 1 uncapped – 1 capped or 2 capped, from 3 lots. For phase 1 testing, will use the cryo disk samples.

Qty	Description	Diameter	Length	Width	Thickness
2s/2l/p1	Disk Sample RT	125mm d			2 mm
2s/3l/p2	"Cube" Sample RT		25 mm	25 mm	25 mm





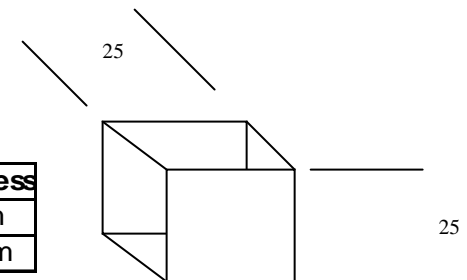
# Phase 1 & 2: X-Ray Diffraction

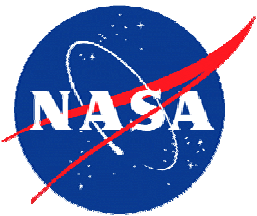
**Objective:** Since many of these materials are multi-phase this test will show how many and which phases are present in the sample. This test can be performed to compare batch-to-batch and intra-sample phase variations. X-ray diffraction can give a current picture of vendor processes.

**Test Method:** The test will be done to ASTM Standard ASTM, D-5758-95

**Sample Description:** For Phase 2 the vendor will supply 2 samples, 1 uncapped – 1 capped or 2 capped, from 3 lots. For phase 1 testing, will use the cryo disk samples.

Qty	Description	Diameter	Length	Width	Thickness
2s/2l/p1	Disk Sample RT	125mm d			2 mm
2s/3l/p2	"Cube" Sample RT		25 mm	25 mm	25 mm





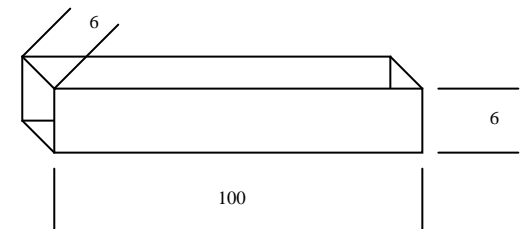
## Phase 2: Coefficient of Thermal Expansion

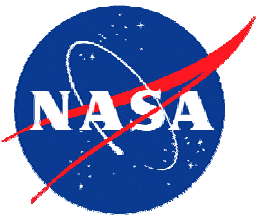
**Objective:** This test will be used to measure the change in length of the test sample due to temperature. For the application of mirrors, the temperature range of interest will be from 200K down to 20K. The testing facility will provide information on system calibration procedures, system accuracy, temperature variations, example of system repeatability and other applicable data.

**Test Method:** Testing contractor will measure the thermal expansion using (ASTM Standard E289 - 95). Measurements will be conducted under vacuum.

**Sample Description:** The samples for this test consists of 2 samples, 1 uncapped – 1 capped or 2 capped, from each of 5 batches/lots. These samples need to be polishable or a mirror will need to be installed on face under test. If the basic material is not essentially isotropic, additional samples will be needed so that non-isotropic property can be determined.

Qty	Description	Length	Width	Thickness
2s/5l/p2	Sample, RT - 20K	100mm	6mm	6mm





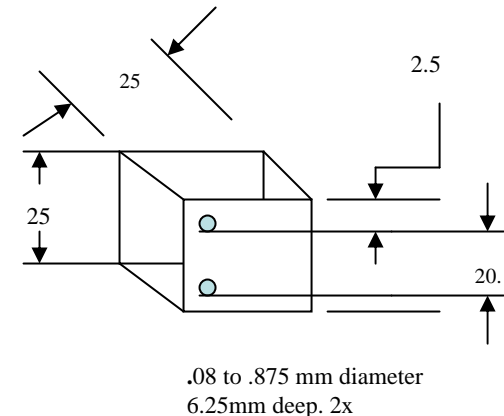
## Phase 2: Thermal Conductivity

**Objective:** To measure the thermal conductivity of sample. Information regarding the thermal diffusivity and specific heat capacity can be obtained.

**Test Method:** This measurement is based on ASTM E 1225.

**Sample Description:** Vendor to supply, 2 bulk samples, or 1 uncapped, 1 capped sample from 5 lots; if only does “capped” then all samples would be capped (This geometry needs to be explored further, TBR.)

Qty	Description	Length	Width	Thickness
2s/5l/p2	Sample, RT - 30K	25 mm	25 mm	25 mm



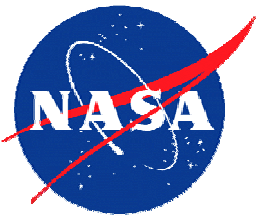


**Sample Description:** Samples would be of “bulk” material only, 4 samples from 5 lots. This is two different tests.

Technical drawing of a mechanical part with the following dimensions:

- Top width: 18.75
- Top hole diameter:  $\varnothing 0.25$
- Bottom hole diameter:  $\varnothing 0.425$
- Bottom hole depth: 0.000
- Bottom hole offset from left edge: 9.375
- Bottom hole offset from right edge: 12.5
- Bottom hole offset from top edge: 21.875
- Bottom hole offset from bottom edge: 12.5





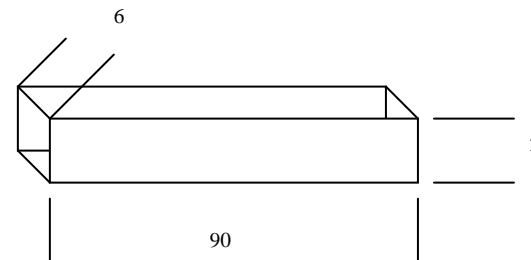
## Phase 2: 4-point Bend

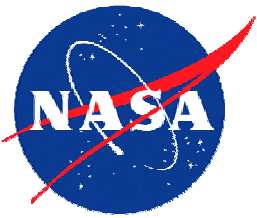
**Objective:** This test will measure the ability of the sample to bend without fracturing. The 4-point Bend test will quantify the amount of stress the sample can withstand prior to material fracture.

**Test Method:** This measurement is based on ASTM C 1421.

**Sample Description:** Vendor to supply, 2 bulk samples, or 1 uncapped, 1 capped sample from 5 lots; if only does “capped” then all samples would be capped.

Qty	Description	Length	Width	Thickness
2s/5l/p2	Sample, RT - 30K	90mm	6mm	2mm





## Phase 2: Fracture Toughness

**Objective:** This test will measure the rate of crack propagation within the test sample. A relatively high fracture is required to control the rate of crack growth. The test will be performed at temperatures ranging from 200 K to 80K with goal of 4 K.

**Test Method:** This measurement is based on ASTM C 1421.

**Sample Description:** Supply 2 samples from 5 lots. Question of capped/uncapped may need to be negotiated.

Qty	Description	Length	Width	Thickness
2s/5l/p2	Sample, RT - 80K	45mm	6.35mm	6.35mm

